This chapter presents three approaches (Approaches B-D) for identifying the benefits of RCRA using pathway modeling of contamination at sample facilities. Relative to the property value method, these approaches would provide more detailed estimates of the range of exposure-related benefits of changes in waste generation, management and disposal practices under RCRA Subtitle C. While Approach A addresses benefits associated with facility closures, pathway modeling approaches identify the benefits associated with improved waste management at operating TSDs. The approaches provide:

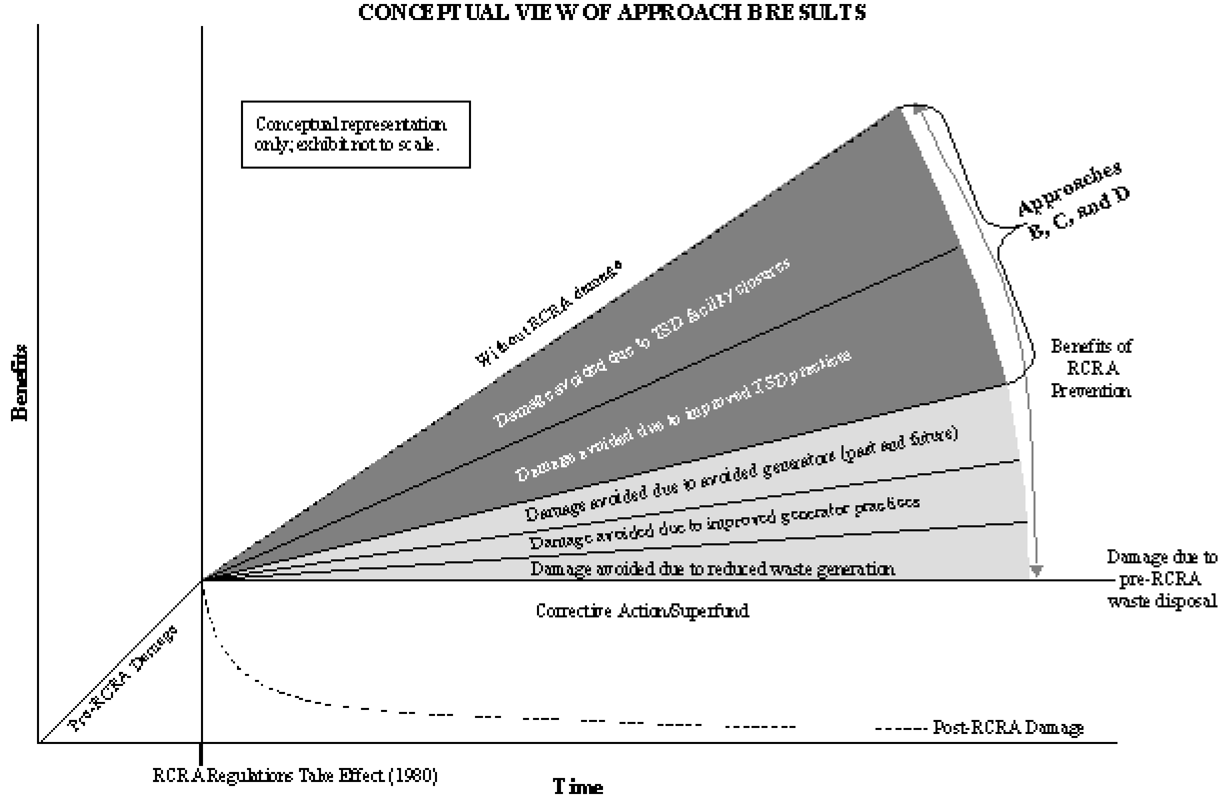
- An estimate of incremental benefits of avoided contamination due to improved waste management practices at operating TSDs. Estimates reflect both changes in quantities of waste managed and changes in failure rates and releases from new waste management facilities. Pathway modeling can be used to identify the effects and probability of potential contamination in a "clean" site, and can also provide an estimate of incremental damages that would have resulted from continued waste disposal (in the absence of RCRA) at a site that was already contaminated in 1980.

- Specific information about the relative contribution of different benefits such as the value of avoided human health effects and the extent of ecological benefits. Pathway modeling methods allow separate evaluation of individual attributes and descriptions of the "environmental outcomes" resulting from the RCRA program; this can be useful in GPRA reporting, comparative risk analyses, or to address other Agency information needs, or in adjusting analyses to reflect new or updated approaches or information in the evaluation of specific attributes.

While pathway modeling focuses primarily on incremental benefits of changing waste management at on-going TSD operations, the approach may also be able to provide an alternative estimate of the benefits described in Approach A (i.e., the benefits associated with facility closures). The ability to extrapolate pathway modeling results to an estimate of avoided hazardous waste sites will depend on the representativeness of the sample of facilities used in the modeling effort. Exhibit 3-1 illustrates the portion of RCRA benefits that may be addressed by Approaches B, C, or D.

Exhibit 3-1

CONCEPTUAL VIEW OF APPROACH B RESULTS



We present three distinct pathway modeling approaches for identifying RCRA Subtitle C benefits. These approaches represent variations of a single approach in that they all model exposure scenarios using site-specific data from a sample of facilities. However, they differ from one another in two ways: they propose different methods identifying a sample of facilities representing RCRA (and without-RCRA) TSDs, and they employ different available pathway models. In consequence, the approaches differ in the certainty of their results and in their ability to extrapolate national benefits estimates from facility samples.

- **Approach B** would provide an assessment of the benefits of Subtitle C regulations based on site-specific information at a sample of RCRA TSD facilities from EPA's *Corrective Action RIA*.

- **Approach C** would use primary data collection and modeling to identify benefits associated with a newly selected sample of facilities.

- **Approach D** would assess the benefits of RCRA by applying the Hazardous Waste Identification Rule (HWIR) 3MRA multi-pathway model, using the sample facilities in this model to represent pre-RCRA facilities.[1]

3.1 ATTRIBUTES MEASURED

Each of the pathway modeling approaches would provide estimates of benefits from avoided human health and ecological impacts. Each would use modeling to project contamination and damage in a without-RCRA scenario and then compare these results to "with-RCRA" damages. Modeling estimates of contaminant levels and duration can then be used to assess the avoided costs associated with contamination, including the government-mandated treatment and remediation costs and voluntary averting behavior and response costs (e.g., community time). In addition, for specific attributes and benefits that cannot be easily measured using pathway modeling (e.g., improved aesthetics and avoided health effects and costs related to acute events), the approaches include separate methodological options to augment the modeling results. The attributes addressed include:

- **Human Health Benefits** from reduced exposure to contaminated air, soil, and groundwater. Pathway modeling can provide estimates of chronic human health effects (e.g., population estimates of cancer and non-cancer effects and estimates of risk to maximum exposed individuals (MEI)). A separate method would address potential health effects related to avoided acute events (e.g., hazardous waste spills or explosions).

- **Ecological Benefits** from reduced surface water contamination and damage to biota and habitats. Pathway modeling can provide estimates of contamination at active facilities. A separate method would address the potential benefits of restrictions on building in flood plains (i.e., the potential reduction in ecological damage associated with flooding events).

- **Avoided Costs** associated with contamination incidents, including government-mandated treatment and remediation costs and costs related to voluntary averting behaviors.[2] Pathway modeling estimates of the extent of contamination provide the basis for estimated clean-up and averting behavior costs.

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[1] Glenn Farber in EPA's Office of Solid Waste has been developing this approach and has provided a general description of the approach in this chapter; the development of a more detailed description of this approach depends on the completion of the HWIR 3MRA model.

[2] While voluntary averting behavior costs typically function as a low-end proxy for willingness to pay to avoid health risks, we present avoided cost methods in one place for simplicity.

- **Improved Aesthetics and Historic Preservation** associated with improved waste management practices. These attributes describe benefits resulting from improved aesthetics (e.g., reduced noise and odors) attributable to improved waste management practices. Reduced impacts on historic landmarks are also considered.

These attributes identify the principal benefits of RCRA that can be estimated using pathway analysis. However, while pathway analysis can be used to provide quantitative estimates of health and ecological impacts over long time horizons, the approaches in this chapter do not specifically address a number of issues related to the long-term benefits associated with RCRA. We discuss the assessment of long-term benefits in more detail in Chapter 4.

The remainder of this chapter outlines the three pathway modeling approaches and the proposed methods for addressing the relevant attributes. We first provide a general outline of Approach B. We then describe potential methods for addressing the relevant attributes within the context of this approach. Finally, we provide general outlines for Approaches C and D. We do not, however, separately discuss methods for addressing attributes under Approaches C and D; these two approaches will likely use variants of the methods discussed in Approach B, but our information about specific models is currently limited and we cannot describe likely outcomes in detail.

3.2 APPROACH B: SITE SPECIFIC MODELING APPROACH USING CORRECTIVE ACTION RIA FACILITY DATA

Approach B directly examines a sample of facilities to identify and evaluate changes in practices. Approach B involves three basic analytic steps: identification and collection of a facility sample; modeling analysis of facility data and identification of avoided damage; and estimation or characterization of attributes related to avoided damage. At each of these stages there are methodological alternatives that vary in required resources and in the comprehensiveness and precision of results.

3.2.1 *STEP 1. Identification and Selection of Facility Sample*

Our proposed Approach B analysis would use the site specific data and models that were developed for the 79-facility sample of the *Corrective Action RIA.*[3] This data set has several distinct

[3] The *Corrective Action RIA* identified 79 sample facilities with pre-RCRA solid waste management units (SWMUs) that would require remediation under Corrective Action if they were (or became) contaminated. We believe that these facilities are likely to be generally representative of facilities with pre-RCRA practices. However, a close examination of facility data is necessary

advantages. First, the facility sample was selected to support a national estimate of the benefits and costs of the Subpart S Corrective Action program. The data set contains facility process information about a nationally-representative group of operating TSD facilities that also have pre-RCRA waste management units on site.[4] This data source, therefore, represents an alternative to a rigorous and extensive sample selection process.

Second, the sample of Corrective Action facilities was used to model the actual and expected contamination from closed (i.e., pre-RCRA) Solid Waste Management Units (SWMUs) on site at RCRA facilities. The baseline of this modeling effort effectively establishes the expected contamination levels for our proposed with-RCRA Subtitle C scenario.

One limitation of this sample is that it may contain several facilities with SWMUs that stopped receiving waste prior to the development of RCRA, and are therefore not relevant to RCRA prevention programs. If this is the case, then the effective sample size for an analysis of the RCRA prevention program may be smaller, affecting the ability to extrapolate results nationally. However, because the 79 sites were active RCRA facilities in 1992, and because many had multiple SWMUs on site, it is likely that there is a sufficient sample of SWMUs and facilities that were affected by RCRA to be able to estimate some national level benefits of the program.

3.2.1.1 Supplemental Data Sources

While Approach B would be based primarily on the *Corrective Action RIA* facility sample and modeling results, we also examined a number of other national data sets that may be useful in supplementing the analysis either by providing additional facility data or by identifying additional facilities if the *Corrective Action RIA* sample is limited. Moreover, these sources may provide useful data about RCRA facilities and contaminated sites that could help inform the development of national estimates of certain benefits:

- **CERCLA Facilities:** The CERCLIS database contains facility information on the extent of existing contamination and environmental damage for NPL and non-NPL sites. For many sites, the Agency has prepared site narratives describing historical operations and waste disposal patterns. Although these sites represent only a subsection of relevant facilities (that is, contaminated

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to verify the extent to which sample facilities are representative of the pre-RCRA universe. The actual number of representative facilities (i.e., the effective sample) may be smaller than 79.

[4] The *Corrective Action RIA* used a stratified random sampling approach that emphasized the selection of facilities with extensive available data. It is therefore possible that the sample may not be representative of all pre-RCRA facilities. A careful evaluation of the sampling protocol and the facilities in the sample is necessary to identify potential bias would affect an analysis of RCRA.

facilities that closed prior to 1980), the site-specific information and range of industries, locations, and contamination levels may be considerable. Sample selection requires identifying facilities with sufficient data that are likely to represent RCRA-related closures (i.e., facilities that were disposing of hazardous waste after 1970 but closed by 1980).[5]

- **RCRIS Facilities:** RCRA programs store facility information in the extensive RCRIS database, which is a collection of previous databases. One drawback of RCRIS is inconsistency in the type and quantity of data. However, the database has permit information on key parts of the population of facilities affected by RCRA, including "converters" (i.e., facilities that obtained Interim Status as TSDs and then ceased managing hazardous waste) and "protective filers" (i.e., facilities that entered the RCRA system but never completed the permit process). Use of RCRIS demands initial research into the availability and quality of specific types of data.

- **BRS Facilities:** BRS tracks only active RCRA facilities, but examination of different BRS reports over time may reveal patterns in closure and changes in the number of industries and facilities regulated under RCRA as new initiatives and regulations have been added. In addition, BRS contains information on quantities and types of waste generated, and may be useful in assessing the benefits of waste minimization efforts under RCRA.

- **State Programs:** Certain state hazardous waste programs maintain comprehensive information about prevention and cleanup activities at all sites. States may provide a broader range of facility sizes and damage incidents than Federal sources because they frequently address "smaller" releases than those addressed by CERCLA or Corrective Action. However, information quality varies by state, along with dominant industries and ecological features; the principal challenge of using these data would be extrapolating them to national results. In addition, if state information is not in a form readily available to the public, then collection of data from more than nine states may require an ICR.

The specific objectives and resources available for an analysis of RCRA will dictate which of these sources is most appropriate for different portions of the analysis, or for supplementing the *Corrective Action RIA* facility sample, if this should prove necessary. We recommend a number of methods based on data from several of these sources in our proposed approaches to various individual attributes throughout the remainder of this report.

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[5] Some CERCLA and RCRIS data may be restricted as enforcement sensitive but we do not believe that this will prevent collection of basic information about facility practices and damage.

3.2.2 *STEP 2. Model Baseline and Without-RCRA Subtitle C Releases*

Our proposed Approach B would develop an estimate of the incremental benefits of improved waste management practices at active RCRA facilities, using all or a portion of the *Corrective Action RIA* facility sample to represent the universe of these facilities. Based on this sample, the approach would next model the expected environmental damage at these facilities in both the with-RCRA Subtitle C and without-RCRA Subtitle C scenarios.

3.2.2.1 Identify Level of Contamination in the Presence of RCRA Subtitle C

The *Corrective Action RIA* analysis modeled the number and size of releases from existing SWMUs on site at sample facilities. The results of this analysis were used to depict a baseline contamination level assuming that Corrective Action cleanup programs existed. The benefits of Corrective Action were then measured by modeling the reduction in damage as a result of expected cleanup activities under the program.

All of the releases modeled in the Correction Action RIA result from waste that was disposed prior to 1982, and has therefore not been reduced or controlled by the RCRA prevention program. As a result, releases modeled in the *Corrective Action RIA* baseline do not directly address RCRA prevention benefits. Instead, they represent the expected contamination level in the with-RCRA Subtitle C scenario because we assume that these SWMUs closed due to RCRA Subtitle C. This approach assumes that the risk of damage from new Subtitle C units at the sample facilities is negligible, due to monitoring and response requirements under RCRA prevention regulations.[6]

3.2.2.2 Model Contamination Levels in the Absence of RCRA Subtitle C

While they did not prevent contamination from existing waste, RCRA Subtitle C disposal standards were responsible for the diversion of waste streams from pre-RCRA SWMUs after 1982. Therefore, the RCRA Subtitle C prevention program is responsible for any incremental benefits of discontinued waste disposal in these units (i.e., for any releases or damage avoided by discontinuing disposal in the units in 1982).

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[6] This assumption may be aggressive, because even stringently regulated and managed wastes may sometimes pose environmental concerns (e.g., due to accidents during handling and transportation of hazardous wastes, or potential risks from constituents such as metals that are difficult to manage using certain practices). The strength of the assumption can be tested using the RCRIS database to identify the actual rate of occurrence of non-compliance and damage incidents at sample facilities. If damage caused by releases from Subtitle C-regulated facilities is significant, then the expected level of contamination in the with-RCRA scenario can be adjusted to reflect this; and the specific contribution of waste minimization efforts should be addressed.

By adjusting the *Corrective Action RIA* modeling to reflect continued disposal of waste in sample pre-RCRA units, we can estimate the total damage that would have resulted if pre-RCRA waste disposal practices had continued at these sites.[7] The benefit attributable to the Subtitle C prevention program is the difference between this "continued disposal" damage and the *Corrective Action RIA*'s baseline estimate of contamination from the sample facilities. This captures the benefits of discontinued waste disposal practices at current facilities.

3.2.3 *STEP 3: Estimate or Characterize Benefit Attributes*

The modeling results in Stage 2 provide estimates of the number and extent of releases and environmental damage that have been avoided by the implementation of RCRA prevention programs. The third stage of Approach B involves estimating benefits associated with avoiding this damage. It is necessary in this approach to address benefit attribute categories separately. There is no aggregate measure of benefits such as the property value estimate in Approach A. However, while separate analysis of individual attributes requires additional effort, it provides the following flexibility that is not available in Approach A:

- The ability to focus on a specific attribute or category of benefits and provide more information on specific environmental outcomes resulting from the RCRA Subtitle C program;
- The ability to revisit and update specific attribute analyses as information improves or as the literature in the field develops.

We present potential methodologies for estimating benefits in the next section of this chapter.

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[7] We expect that the facility information that was collected during the development of the *Corrective Action RIA* will be sufficient to support an estimate of facility production, waste generation, and disposal rates. To address continued waste disposal practices we propose to identify a range of scenarios, including a scenario that predicts continued disposal at a constant rate, and scenarios that suggest declines in waste generation (e.g., due to technology improvements) and increases in waste generation (e.g., due to facility growth). For cases in which facility-specific data are not sufficient to develop a scenario of continued disposal, we propose to supplement facility-specific information with industry-level data in EPA's *Industry Assessments* to develop a reasonable disposal scenario for a representative facility.

3.2.4 *STEP 4: Apply Modeling Results to "Avoided TSDs"*

The modeling scenarios in Step 2 identify incremental damages that would have occurred if waste continued to be managed in certain SWMUs. These results should be representative of TSD facilities in the Corrective Action universe (i.e., operating facilities that changed practices under RCRA).[8] In addition, these results can also provide an alternate estimate of the benefits associated with facility closures (i.e., an alternative to the property value-based result of Approach A). This alternative would apply the average avoided contamination level identified in Step 2 to the number of "avoided TSDs" (subject to the same uncertainties) identified in Approach A. The result would be an estimate of total avoided contamination associated with TSDs that closed under RCRA. This step would require the following calculations:

- Identify the range of avoided damages at RCRA facilities (based on modeling results from Step 2) and adjust this avoided damage estimate to reflect the total universe of facilities estimated in the *Corrective Action RIA*; this would provide a national estimate of avoided damages due to improved practices at ongoing facilities;

- Apply the range of avoided (without-RCRA) average per site damage estimates calculated for the sample facilities to the "avoided TSDs" identified in Approach A.[9] This would provide an estimate of the avoided damage due to facility closures; and

- Add the results of these two analyses to provide a total estimate of the damage avoided by RCRA regulations at TSDs.

The avoided damage from closures under Approach B can be measured simply by applying the range of damages identified at existing facilities to the number of avoided facilities, including both "clean" facilities and those with existing damage that were eliminated from consideration in

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[8] The extent to which these results can be applied nationally will depend on the extent to which facilities and SWMUs in the *Corrective Action RIA* facility sample are representative of units that were affected by RCRA.

[9] Note that a simple extrapolation of the range of damages from the *Corrective Action RIA* to theoretical "avoided facilities" assumes that the avoided facilities would look like the facilities in the *Corrective Action RIA* sample. This extrapolation can be adjusted if available information suggests that *Corrective Action RIA* facilities are not representative of avoided TSDs. Remaining uncertainty can be addressed with a sensitivity analysis.

Approach A.[10] As in Approach A, however, it is necessary to develop a range of estimates to reflect possible differences in the profile of existing contamination at facilities in the *Corrective Action RIA,* and the profile of existing contamination at facilities that closed under RCRA. Exhibit 3-2 shows a flow chart illustrating the calculations in Approach B.

3.3 PROPOSED METHODOLOGIES FOR BENEFITS ATTRIBUTES

The Approach B modeling effort provides data that define the extent of avoided contamination associated with improvements in waste management under the RCRA Subtitle C program. These data, in turn, inform a set of analyses that would estimate the benefits associated with avoiding this contamination. Below we propose methodologies for assessing human health benefits, ecological benefits, avoided costs, and aesthetic and historical benefits associated with RCRA Subtitle C program. These methods rely primarily on the data and modeling results available under Approach B. In addition, while the *Corrective Action RIA* data are sufficient for some of the methods we propose, we also recommend additional data collection or additional analyses to address aspects of attributes that Approach B modeling data do not adequately address.

3.3.1 *Human Health Benefits Related to Chronic Exposure*

An important potential benefit of RCRA is the avoided human health effects associated with exposure to hazardous waste. Because of the large number of different chemical constituents and waste types addressed by the law, avoided health effects include a range of individual and population cancer and non-cancer risks. Although these effects are usually the result of chronic exposure over a long period of time, improved waste management under RCRA may also prevent acute health effects related to exposure from accidents; we address acute events separately below.

Furthermore, exposure to the variety of wastes regulated by RCRA can occur through one or more of several pathways, including ingestion or dermal exposure (e.g., through showering) to contaminated water, inhalation of airborne contaminants, or exposure to soil contaminants through agricultural products or dermal contact. Actual exposure levels are dictated by the site specific variables of geography, hydrology, and the level and type of resource use in the vicinity of a facility. A large release at a facility in a remote area with impermeable soil may not create a measurable human health risk, while a smaller leak in a densely populated area or near an aquifer used for drinking water can have considerable effects.

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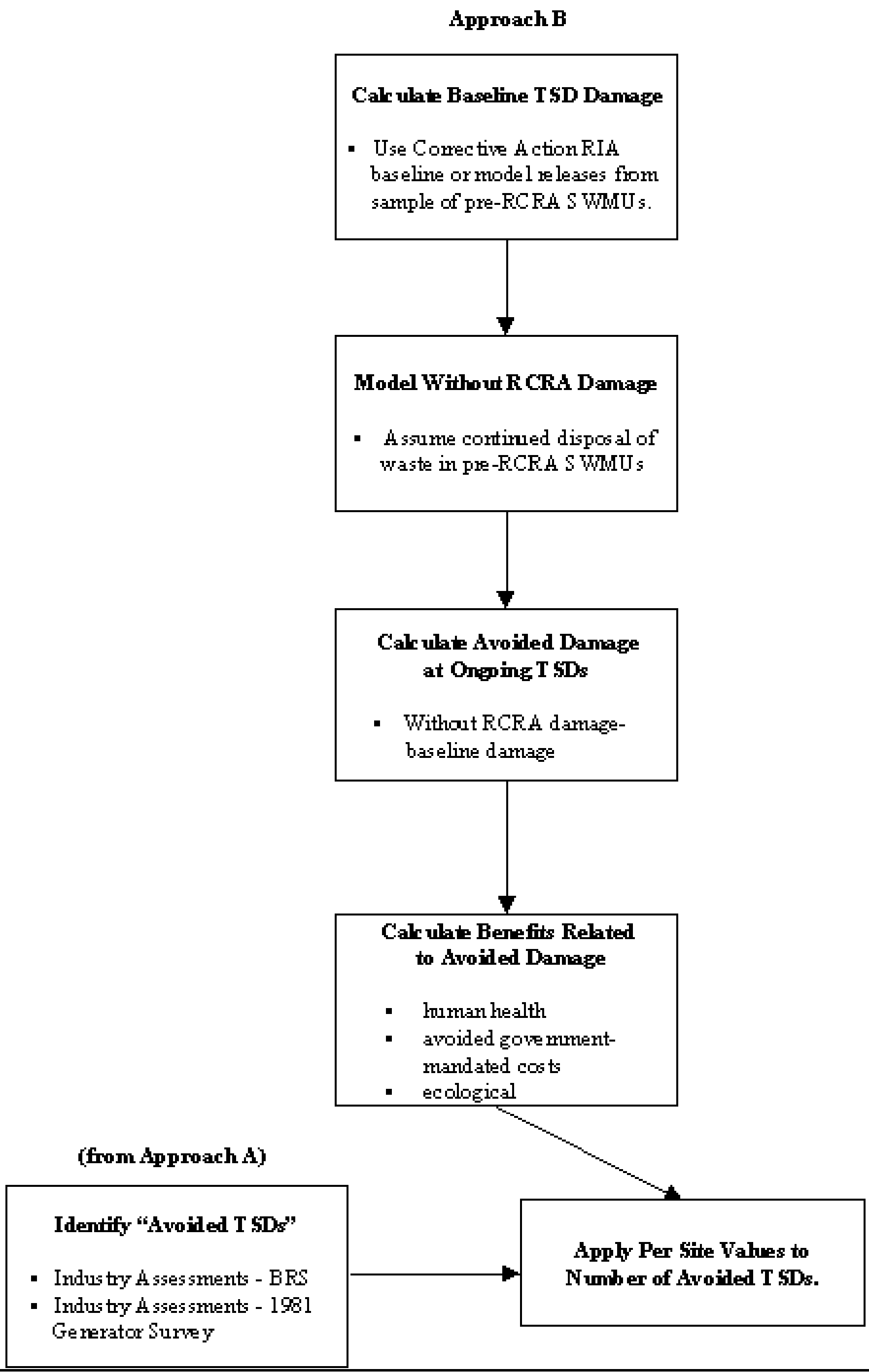
[10] Refer to Exhibit 3-1 for a representation of the portion of benefits and impacts captured under Approach B.

Exhibit 3-2

SUMMARY OF APPROACH B TO ESTIMATING RCRA BENEFITS



Multiple pathway exposure modeling is the most appropriate method for effectively addressing and estimating human health risks in the wide variety of scenarios that occur under RCRA. The standard approach for benefits analysis using multiple pathway exposure modeling involves the following steps:

- Estimating the environmental transport of contaminants through soil, air, and other pathways under a range of with-RCRA and without-RCRA release scenarios;

- Identifying the human "exposure points" in the vicinity of the facilities (e.g., nearby homes, drinking water wells and agricultural land); and

- Applying estimates of the value of avoiding the expected health effects that result from these exposures.[11]

The site-specific data required for characterizing avoided releases under Approach B should be sufficient, if carefully collected, for developing a modeled estimate of the range of human health risks associated with exposure. The sample of 79 facilities in the *Corrective Action RIA* forms the basis for a national estimate of the human health benefits of the Corrective Action program. The RIA uses MMSOILS to model the baseline and Corrective Action exposure scenarios and derives cancer and non-cancer benefits estimates based on exposure scenarios from the model. In addition to their potential use in developing an estimate of total environmental damage avoided by RCRA, these data can provide a baseline estimate of human health risks at ongoing TSDs.

Method:

- Use the *Corrective Action RIA* baseline to identify human health risks from old waste disposal in the presence of RCRA (i.e., units that closed due to Subtitle C);

- Re-run the Corrective Action models to determine exposure to continued waste disposal in the absence of RCRA;

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[11] The statistical value of a human life is frequently used to monetize the population-level benefits of cancer risk reduction and has been applied in other scenarios. This value, and its application in different types of analysis, is itself the subject of ongoing discussion among economists, but its application is an established practice. The selection of a value would be done in accordance with EPA's *Guidelines for Performing Economic Analyses* as part of the design and implementation phase of this project.

- Estimate the economic value of the differences in human health risks under the two scenarios; and

- Apply the range of results from this methodology to the Approach A estimate of avoided TSD facilities.

The *Corrective Action RIA* provides an estimate of both population risks and "MEI" risk; MEI risk in this case would addresses those individuals who represent the top ten percent of exposures associated with waste in closed pre-RCRA SWMUs. The RIA modeling effort attempted to address all damage associated with closed SWMUs (including future human health risks from past releases) and developed a present value estimate of the monetized avoided risks. A revised model would likewise predict future damages associated with "past" waste disposal by modeling continuation of disposal from 1982 until the present time. Potential adjustments to the original modeling assumptions may include updates in estimates of future population density, potential changes in assumptions about the calculation of a present value of human health risks, and revisions to model inputs to reflect new research in health effects or exposure analysis. In addition, the methods for valuing avoided health effects should be carefully reviewed.

Advantages: This approach uses published data and a reliable methodology, and does not require significant additional collection of site-specific data for the development of a modeled estimate of the benefits of changes in management practices at operating TSDs. Assuming that the *Corrective Action RIA* sample facilities are representative of RCRA TSDs, the method would provide a national estimate of avoided population and MEI risks associated with improvements in waste management under RCRA.[12] The approach identifies the benefits of "original" RCRA program regulations.

Disadvantages: The results of this approach are limited to practices at TSD facilities, and does not address generators under RCRA. In addition, the approach does not address newer RCRA regulations because it looks only at SWMUs that ceased operations by 1982. Finally, the effort required to re-examine facility data and re-program the MMSOILS model is likely to be considerable.[13] Note that while the original modeling protocols have been well documented, the effort required to recreate the original modeling results and adjust the model for the without-RCRA scenario would be significant. For example, the *Corrective Action RIA* was concerned with the risks associated with pre-RCRA SWMUs. As a result, the modeling did not emphasize air releases because most volatilization had already occurred. In contrast, the modeling effort required to predict

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[12] Reduction in the number of MEIs, however, would not represent a separate, additive health benefit to reduction in population cancer risk.

[13] In addition, EPA's Science Advisory Board (SAB) identified the limitations of MMSOILS in its peer review of the *Corrective Action RIA*; to the extent that newer versions of MMSOILS have not addressed these limitations, Approach B would require addressing the SAB concerns.

without-RCRA exposures would need to include potential air releases associated with continued waste disposal. Exhibit B-1 in Appendix B contains a summary description of this methodology, along with methods for estimating human health benefits recommended in other approaches.

3.3.2 *Acute Events*

In addition to reducing the risk of health effects from chronic exposure, the RCRA Subtitle C program may provide significant benefits by reducing the frequency and severity of acute events. While these benefits are difficult to identify and monetize, they may include human health effects, ecological damage, and costs associated with emergency response and cleanup.

We briefly examined two aspects of potential benefits of RCRA associated with acute events: reduction in the overall frequency of events, and reduction in the probability of infrequent but catastrophic events. The results of our screening analyses were inconclusive, but suggest that further examination of these issues may be useful. We therefore provide a brief summary of our analyses and propose methods for further examining this issue.

3.3.2.1 Frequency of Acute Events

The number of acute waste-related events appears to have declined since adoption of RCRA. ICF (1996) reports 370 hazardous waste acute events in a three year, post-RCRA period (1993-1995).[14] In contrast, review of the *EPA Hazardous Materials Incidents Reported to U.S. EPA Regional Offices* document (1980) suggests a conservative estimate of 620 hazardous waste acute events in a comparable pre-RCRA time frame.[15] Thus, the frequency of acute events has been as much as halved (i.e., from over 200 per year to roughly 120 per year) since the adoption of RCRA.[16]

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[14] ICF. "Memorandum: Results of Analysis on Releases from Waste Facilities." (1996).

[15] EPA. *Hazardous Materials Incidents Reported to U.S. Environmental Protection Agency Regional Offices from October, 1977 through September, 1979.* Washington, D.C.: EPA. (1980).

[16] The EPA *Hazardous Materials Incidents* report does not distinguish hazardous waste incidents from hazardous materials incidents. However, the document does divide reported incidents into thirteen categories of events. We assume that three of these categories (storage, waste disposal, and treatment) provide a conservative estimate of hazardous *waste* events. This estimate is conservative as it excludes categories that most likely include some hazardous waste incidents, such as rail, truck, fire and miscellaneous. Since the EPA report covers a two year period, we scale these results to a three year period (by assuming a constant number of annual events) to make the EPA results comparable to the ICF results.

Despite the significant decline in the occurrence of acute events, the total number of events both before and after adoption of RCRA appears to be relatively small, and available data do not provide estimates of typical costs or health effects associated with acute events. While some events may require considerable response costs (e.g., evacuations) and may impose significant health risks, others may involve little more than stabilization and removal of spilled waste. As a result, it is not clear whether the overall reduction in acute events under RCRA is associated with significant benefits. Because of the small number of events both before and after RCRA's passage, average costs per event would have to be quite high to be significant relative to other costs and benefits of the RCRA Subtitle C program.[17] While we anticipate that avoided costs associated with acute events would not be significant given the relatively low occurrence of events, willingness to pay to avoid health effects related to acute events could be considerable. However, we are not aware of reliable empirical data identifying willingness to pay to avoid acute events.

Method: To better determine the benefits associated with a reduction in the frequency of acute events, we propose a detailed examination of a sample of the events reported in both the ICF study and the 1980 EPA report, to determine the extent of costs and health effects associated with emergency responses. In addition, we suggest a review of the risk communication and valuation literature to identify any new research that presents an estimate of the value associated with avoiding acute events similar to those prevented by RCRA.

3.3.2.2 Reduced Risk of Catastrophic Events

Though the frequency and anticipated average cost of acute events may be relatively low, RCRA regulations may reduce the risk of infrequent but catastrophic events, such as the Bhopal event in India in 1984. In this case it is worth characterizing and monetizing the benefits of avoiding such disasters. EPA (1996) developed an approach for estimating the costs associated with catastrophic events based on the probability of occurrence.[18] The study characterizes the probability of an event equivalent to the Bhopal disaster, and the probability that such an event would occur in the U.S. This probability is then applied to estimates of the total costs (human health, environmental, economic) of such a disaster. Based on that benchmark, the study extrapolates annual costs of catastrophic events.

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[17] For example, if the average "value" of avoiding an event were one million dollars (reflecting both avoided response costs and willingness-to-pay to avoided health effects), then the total annual benefit associated with acute events avoided under RCRA would be roughly $100 million (based on the above data sources). In comparison, total 1994 *private sector* RCRA expenditures were roughly $2,500 million, excluding costs to government or society at large.

[18] EPA. *Economic Analysis in Support of Final Rule on Risk Management Program Regulations for Chemical Accident Release Prevention, as Required by Section 112(r) of the Clean Air Act.* (1996).

A similar method could be applied to the potential for catastrophic events involving pre- and post-RCRA hazardous wastes. However, catastrophic waste-related events appear to be rare. Our preliminary examination of the Acute Hazardous Events Database (1985) and two EPA studies did not identify any hazardous waste-related events of "catastrophic" magnitude as defined by impacts on human health.[19] The infrequency of events and the limitations of available data make it difficult to identify a baseline of catastrophic events against which to measure RCRA. As a result, while the costs savings and willingness to pay to avoid catastrophic events could be considerable, it is difficult to determine the change in probability of such an event under RCRA.

Method: One possible approach is to conduct case studies of catastrophic events. This might require going back in history to examine past U.S. events or looking outside the U.S.. One example would be a case study review of the damage and cost estimates associated with the recent mining waste releases in Romania. While these incidents took place outside the United States and likely involve "Bevill Amendment" waste that is exempt under RCRA, they may provide a useful "worst case" benchmark for hazardous waste-related accidents. If the accidents did involve RCRA wastes and/or waste management practices discontinued under RCRA (e.g., the use of surface impoundments for hazardous waste), then it might be possible to estimate the extent to which RCRA has reduced the probability of such events. Exhibit B-1 in Appendix B contains a summary description of our proposed methods for addressing acute events.

Note that RCRA may also reduce the frequency of waste-related damage during catastrophic events such as floods. While releases during floods are clearly acute events, the magnitude of flood damages makes it difficult to isolate health benefits or clean-up costs associated with hazardous waste releases. We therefore address the potential reduction of flood damages in our discussion of ecological benefits below.

3.3.3 *Ecological Benefits*

RCRA prevention primarily addresses land disposal practices. As a result, releases to land are the type of polluting event most often avoided by regulation. The effects of land releases can include contamination of soil and groundwater, surface water, and some types of pollution by air. The potential for ecological damage varies with geography and constituent. For example, some constituents when released into the air can be carried and deposited at a relatively great distance from

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[19] IEc. *Acute Hazardous Events Data Base.* (1985); EPA. *Estimating Potential Casualties from Acute Events at Emergency Response Sites*. (date unpublished); EPA. *Hazardous Materials Incidents Reported to U.S. Environmental Protection Agency Regional Offices from October, 1977 through September, 1979.* Washington, D.C.: EPA. (1980). One recent event that may be classified as catastrophic is the large releases of waste from gold mines in Romania in early 2000. However, the ecological and human health damage from this event and the costs associated with its cleanup are still unclear.

the point of release. Others may have health and ecological impacts only at short distances from the release point, due to their instability.

Measurable damage to ecological resources from land releases generally occurs when groundwater or overland flow of water carry contaminants to a nearby surface water body. Flood events and other acute incidents can cause releases of waste that have an immediate and significant effect on ecological resources (e.g., a surface impoundment dike fails and releases contaminants into a river, killing fish and other biota). More common are gradual increases in contaminant levels due to long-term releases to groundwater. These may have a broad array of impacts on both resources used by humans (such as fish populations) and on "non-use values" such as the value of preserving habitat and species diversity.[20] In addition, biota can be affected by uptake of contaminants from soil, particularly in wetlands or areas where the water table is high. Relevant ecological impacts and benefits will vary with specific sites.

RCRA may have other ecological benefits related to the location and operation of newer TSDs. Approach B incorporates an initial assumption that there is *de minimis* risk from Subtitle C facilities so consideration of new TSDs is not necessary. However, this assumption may underestimate risk from these facilities, particularly from catastrophic events such as major floods. If the analysis is adjusted to incorporate potential risks from Subtitle C units, then the various construction and siting requirements related to these units should be considered in an evaluation of program-wide improvements.

We propose two approaches for addressing different aspects of ecological benefits. First, we present an approach for addressing ecological effects related to changes in practice at TSDs: this approach is based on, but also expands on, *Corrective Action RIA* modeling and data. Second, we propose a single approach for identifying the effects of RCRA siting requirements that are protective of flood plains and other ecologically sensitive areas.[21]

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[20] The value of preserving habitat and species diversity can include use values as well as non-use values. We use the terminology here to emphasize that analysis should recognize both use value and non-use value when assessing ecological benefits.

[21] Note that we do not specifically address ecological benefits associated with the preservation of groundwater because there is no established method for addressing the non-use value of groundwater, and it is unclear whether groundwater is, in fact, understood by most people to be an ecological resource. However, we address the use value of groundwater in our discussion of avoided costs below in Chapter 3, and we discuss the long-term issues related to the preservation of groundwater (e.g, "assurance" and bequest values) in our discussion of Long Term Benefits in Chapter 4.

3.3.3.1 Model Ecological Benefits Using Multi-Pathway Analysis

The *Corrective Action RIA* modeled baseline ecological damage to surface waters at 52 facilities with SWMUs. While this sample was not specifically selected to emphasize geographic distribution or proximity to ecological resources, adjustment of the model to identify the ecological impact of continued pre-RCRA waste disposal at these facilities can reveal information about the potential importance of prevention. While results of this modeling should not be applied on a national level without adjustment, a supplementary sampling effort or a careful benefits transfer analysis may provide the basis for a reasonable national estimate. Without a close examination of facility data from the *Corrective Action RIA*, it is not possible to identify specific approaches to national extrapolation. However, we do provide a description of a general modeling approach using *Corrective Action RIA* data.

Modeling is the most effective approach to identifying the ecological benefits of RCRA at a variety of facilities with varying wastes, varying quantities, and varying proximity to fragile and valuable ecosystems. Although modeling of ecological resources has intensive data requirements, many of the most important types of environmental data are readily available in spatial form. The facility-specific data and MMSOILS baseline analysis associated with the *Corrective Action RIA* provide a reasonable starting point for an analysis of incremental effects.

Method:

- Use the baseline MMSOILS model results from the *Corrective Action RIA* to identify with-RCRA Subtitle C damage.

- If data are available, expand modeling to additional pathways such as air and soil (the original analysis examined only surface water) and identify any additional effects.

- To identify avoided damage, revise the model to predict expected releases and damage from SWMUs assuming continued waste disposal in the absence of RCRA Subtitle C.

- Characterize damage avoided by RCRA, and establish values for impacts based on literature or benefits transfer methodologies. Note while some benefits such as the value for commercial and recreational fishing can be assigned monetary values, other ecological benefits such as preserved habitat may be difficult or impossible to monetize.

- If specific risk drivers are identified (e.g., proximity to a specific type of resource, geology, or industry type) a scoping analysis of the potential risk driver can identify possible national level benefits (e.g., a spatial analysis of the number of facilities located in riparian zones).

Advantages: This approach provides detailed modeling results that can contribute to analysis of a variety of different ecological benefits. It also allows construction of state-of-the-art geographic information system that can be updated as methodologies advance.

Disadvantages: The approach may require significant effort if modeling extends to facilities beyond the *Corrective Action RIA* sample. Also, the ability to extrapolate results to national level may be limited by previous sampling priorities. Finally, most available models are not able to measure acute events such as floods.

3.3.3.2 Assess Effects of Subtitle C Facility Siting Requirements

One potential benefit of RCRA is improved siting of new TSD facilities due to regulations that require facilities to be located away from flood plains and other sensitive ecological areas. While site requirements have a limited effect on existing facilities, a simple analysis comparing the locations of new and "older" RCRA TSDs may identify significant ecological protection benefits not captured in the approaches outlined above.

Method: Our proposed method for examining this potential benefit is a spatial analysis using a geographic information system (GIS) to identify the proximity of flood plains and other sensitive locations to RCRA facilities. Data in RCRIS and BRS can be used to identify pre-RCRA siting decisions (i.e., TSDs that applied for interim status in 1980) and more recently regulated facilities. Using geographic data from the United States Geological Survey, National Oceanographic and Atmospheric Administration, and other public sources to identify ecological features, a simple analysis of the percentage of facilities in close proximity to fragile systems can identify the extent of change in siting decisions under RCRA.[22] In addition, a supplemental analysis of high water data for recent large flood events (e.g., the 1993 Mississippi River floods) and multiple years of BRS data may allow identification of specific facilities that ceased managing waste prior to flood events.

The results of this analysis are not additive with the results of the multi-pathway ecological analysis because it is impossible to predict what facilities "would have been sited" absent RCRA. However, an identifiable trend toward siting decisions that are protective of ecological resources is a clear benefit of the program that can be presented in conjunction with the above approach.[23]

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[22] This analysis assumes that, absent RCRA, spatial distribution of RCRA facilities would be similar to the distribution of pre-RCRA facilities that still exist.

[23] Flood-related hazardous waste releases would also likely include materials damage and human health effects, but these effects would be difficult to isolate from general flood damage, and may also be included in an analysis of acute events. Our discussion of the benefits of RCRA siting requirements therefore focuses only on ecological impacts.

Exhibit B-2 in Appendix B contains a summary description of these two methodologies, including a brief description of data requirements for each.

3.3.3.3 Note on Resource Conservation Benefits

Our proposed methods for characterizing the ecological benefits of RCRA do not address "resource conservation benefits" associated with reductions in the quantity of hazardous waste generated under RCRA. Reduced waste generation may be associated with reduction in the extraction and use of raw materials. Avoided ecological damage associated with the extraction of raw materials should be considered a benefit of RCRA.[24] However, at this time we have not examined available data sources or considered potential methods for addressing these benefits. We recommend that this potential source of benefits be revisited as part of implementation.

3.3.4 *Avoided Costs*

The "avoided costs" attribute is often difficult to define and measure, particularly in the context of a prevention-related program. A central purpose of the RCRA Subtitle C prevention programs is to avert environmental damage and its associated costs. Therefore, many benefits of RCRA may be expressed as "avoided costs" and some avoided costs are captured in other attributes. However, here we specifically address the costs associated with government mandated and voluntary treatment or "averting behaviors" to avoid the effects of contamination. Government mandated treatment costs avoided by RCRA Subtitle C are not captured by other attributes and may have a significant impact on the overall value of the program. Voluntary averting behavior costs may also be considerable and may be useful in estimating the full value of avoiding health impacts. Our proposed methods address the avoided costs associated with obtaining alternative water supplies.

Because most releases of waste from hazardous waste facilities are releases to land, contamination of groundwater is a primary exposure pathway. The costs related to this damage include the incremental costs of switching to a new water supply. This can mean purchase of bottled water, connection of homes to a municipal water supply, or installation of water treatment for an existing supply. In any situation where contamination requires installation of a more expensive water supply mechanism, the avoided costs of averting health effects include the switching costs and any incremental water costs. Note that while other types of exposure (e.g., ingestion of food grown

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[24] Note that conservation of finite resources represents a transfer of goods across time and may or may not be associated with an economic benefit. Actual economic benefits would be determined by the extent to which the future value of the resource is affected by scarcity, demand, and availability of substitutes. However, resource conservation is often a stated goal of a particular policy or regulatory program and it may also be important to identify the extent of resource conservation as part of a comprehensive assessment of a program.

in contaminated soil or water) may require changes in behavior, in most cases we believe that switching costs are negligible (e.g., since most populations are not exclusively dependent upon local food sources).[25] Finally, this definition of avoided costs is conservative in that it does not consider behavior changes with no obvious replacement cost, such as the need to reduce showers or outdoor activities in order to limit dermal exposure to or inhalation of VOCs and other contaminants.

One issue in estimating avoided water supply benefits is the potential overlap with human health risks, since averting behavior should reduce risks to health, even before site remediation is complete. A simple approach assumes that all exposure-related human health risks are fully mitigated by averting behavior at the point in time when public notification of risk occurs (for simplicity we also assume that notification is simultaneous with the beginning of site remediation). Therefore, the duration of human health risks is defined as the interval between initial exposure and the public notification of risk.[26] The value of avoided costs is then added to human health risk estimates.[27] Exhibit 3-3 illustrates this view of a hypothetical damage incident and its associated impacts; additive costs represent the sum of other costs in the figure. Note that any implementation of these methods should carefully define exposure duration and averting behavior costs to assure that there is no double-counting of these impacts.

Our proposed Approach B would address both the avoided costs associated with improved practices at active TSDs and the benefits associated with avoiding hazardous waste sites. Therefore, each avoided cost estimate would incorporate two calculations: an assessment of benefits associated with operating TSDs (removing from consideration remediation and response activities in the with-RCRA scenario), and a separate estimate of avoided costs associated with avoided hazardous waste sites. Below we present two alternative approaches to calculating avoided water costs. Within each of these methodologies we address both existing and avoided TSD facilities.

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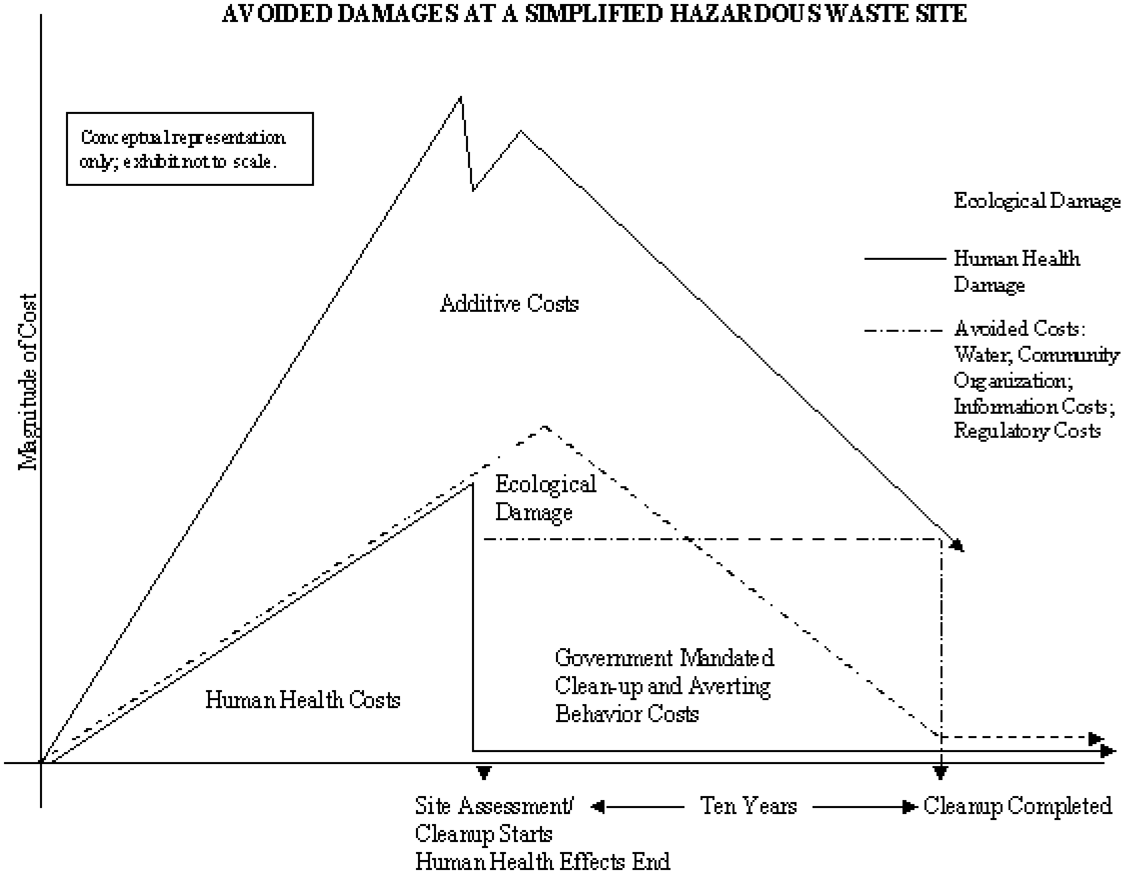
[25] In some cases where certain populations are dependant on a specific food source this assumption may not be valid. The environmental equity attribute addresses the distributional effects of contamination on sensitive populations and can be used to identify cases where this issue arises.

[26] This simplifying assumption does not address circumstances in which persons continue to be exposed to risk (e.g., through refusal to take averting actions, lack of notification, or exposure to "unavoidable" risks such as air transport of pollutants from a site). In these cases averting behavior-related costs may serve as a rough substitute for the continuation of human health risks.

[27] Implementation of any modeling approach must address the issue of assessing total impacts; one approach could be to model perpetual human health impacts to estimate extent of environmental damage. Alternatively , it may be preferable to model more limited health impacts and consider clean-up and averting behaviors. The actual extent of health risks and averting behaviors vary with site specific characteristics. The modeling approaches suggested for human health effects will require identification of expected duration and timing of contamination and health effects, or consideration of avoided costs on a site-specific basis.

Exhibit 2-3

AVOIDED DAMAGES AT A SIMPLIFIED HAZARDOUS WASTE SITE



Note: We assume that health effects are completely mitigated by averting behavior (and thus decline to zero) as soon as risks are known. We also assume that the beginning of site cleanup is simultaneous with notification.

3.3.4.1 Option 1. Simple Extrapolation of Existing Estimate

The *Corrective Action RIA* modeled baseline avoided costs of providing alternative water supplies. One very quick estimate of costs can be generated by assuming that water supply damage (and replacement costs) have a linear relationship with the spatial extent of contamination. This estimate uses modeling data generated for the human health benefits evaluation above to compare the spatial extent of affected groundwater resources under the without-RCRA scenario with that identified in the baseline. Then the RIA's total estimate of $230,000,000 (in 1992 dollars) can be adjusted by the same percentage.[28] The RIA's total estimate can also be adjusted to provide an

[28] Note that we use groundwater volume as a metric because we assume that well access is determined by property ownership patterns and not by aquifer volume. However, we suggest a bounding analysis using change in percentage volume affected to reflect an assumption that the well access is determined by the extent of the resources and does not conform to property lines.

estimate of the avoided costs associated with the total number of avoided facilities identified in Approach A. This assumes a simple linear relationship between cost and number of affected facilities, and assumes that the Corrective Action universe is representative of the avoided facilities. The simple calculations for this approach are:

Avoided Water Costs at operating TSDs =

area affected groundwater (without RCRA)/area affected groundwater (baseline) × baseline total avoided costs

Avoided Water Costs at avoided TSDs =

(average replacement costs per site (RIA baseline)) × # avoided TSD's (Approach A)

Total RCRA avoided water supply benefits =
Avoided Costs at operating TSDs + Avoided Costs at avoided TSDs

Advantages: This option provides a simple characterization of the extent of water replacement costs avoided under RCRA without requiring significant data collection.

Disadvantages: The result of this option is based on the assumption that relationships between the extent of damage (either spatial extent of pollution or number of facilities with releases) and avoided costs are linear. This assumption obscures the fact that avoided water costs are "project-defined." For example, the two long-term options for alternative water supply (treatment and extension of municipal systems) require significant capital investments, but the marginal cost of "adding another house" to an extended system may be insignificant. Also, the approach requires the designation of an "average time span" for contamination in order to designate plume sizes; this estimate will contribute uncertainty to the analysis. As a result, the estimates identified in this methodology are most useful for scoping purposes only.

3.3.4.2 Option 2: Calculate Benefits Using Modeling and Site-Specific Data

Option 2 addresses the issue of cost variability by using *Corrective Action RIA* sample facility data to model the extent of additional without-RCRA disposal effects in real settings. The *Corrective Action RIA* outlines an approach that incorporates actual well use data and existing water supply options into its baseline avoided cost estimate. An approach that reproduces or updates this methodology will provide a more specific and reliable estimate of avoided costs.

Method:

- Define with-RCRA scenario using *Corrective Action RIA* data to determine the following: affected population of well users for each sample facility; likely alternative water sources for each site (e.g., municipal water sources or wells not in the path of contamination); and costs associated with the most reasonable option for each facility, based on engineering estimates borrowed from the literature or generated for the project.[29]

- Modify model to determine extent of groundwater contamination in a without-RCRA scenario.

- Using *Corrective Action RIA* engineering cost and site specific data, estimate the total costs of without-RCRA alternative water supplies, and calculate the benefit by subtracting the with-RCRA estimate.

- Extrapolate results to existing TSD facilities with on-site pre-RCRA SWMUs.

- Estimate costs associated with avoided facilities by applying the ratio of without-RCRA to with-RCRA costs to the number of avoided TSDs identified in Approach A. Like Option 1, this approach assumes a linear relationship between value of the benefit and number of affected facilities.

Advantages: This option would provide a more defensible estimate of avoided costs by using actual site information and project cost estimates. The approach addresses the possibility that marginal avoided costs at a site already contaminated might be very different than total project costs.

Disadvantages: The approach may require significant effort if additional or updated facility data collection becomes necessary. If the effort requires consistent data collection from more than nine individual facilities, then an ICR may be necessary. Exhibit B-3 in Appendix B contains a summary description of our proposed methods for addressing avoided costs.

3.3.5 *Improved Aesthetics and Historic Preservation*[30]

Although RCRA Subtitle C regulations do not directly address the preservation of historic districts or improved aesthetics, better waste management practices may have incidental benefits,

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[29] The likely population of well users must reflect expected population growth and land use transitions in predicting future exposure incidents related to pre-RCRA wastes. The *Corrective Action RIA* presents a method for addressing this issue over the time frame identified in that analysis, but this issue should be addressed again carefully in developing an analysis of RCRA Subtitle C.

[30] This attribute is for consideration in Approaches B, C and D. The value of aesthetics and historic preservation are already reflected in the property values that form the basis of Approach A, though these values do not include non-residential benefits such as improved revenue from tourism.

including reduction in noise and odor and improved visibility in the immediate vicinity of TSD facilities. In addition, TSD facilities near historic districts or open spaces such as parks might affect the quality of experience in these places; regulations mandating appropriate waste treatment might therefore improve the quality of the resources. Alternatively, RCRA regulations that result in a facility owner/operator having to transport their waste for off-site storage, treatment, or disposal to ensure effective management may increase truck traffic and noise, and may actually reduce aesthetic quality. It is even possible that total benefits under this attribute could be negative if new RCRA facilities are larger and more disruptive than older facilities.

There are three difficulties in addressing aesthetics and historic preservation in the RCRA context. First, because impacts on these attributes are indirect results of RCRA, there is no national effort to collect information to identify these effects. Second, the attributes and their values are very localized and require site-specific evaluation.[31] Finally, it is difficult to attribute benefits to RCRA because other environmental laws (e.g., the Clean Air Act) also affect aesthetics and the preservation of historic landmarks. For these reasons we limit our range of approaches to those that will characterize the possible importance of these attributes without demanding considerable resources. We recommend four methodological options. The first two options address aesthetic improvements; the third addresses historical preservation, and the fourth is an integrated approach that addresses both improvements in aesthetics and historic districts in the vicinity of RCRA facilities.

3.3.5.1 Potential Benefits to Aesthetics Under RCRA

Option 1. Identify Correlation, Trends Between RCRA Sites and Reported Disamenities. The American Housing Survey from the U.S. Census asks residents in various metropolitan regions to report on the features of their housing, including environmental disamenities such as noise, smoke, and traffic. Based on data from various years of this survey and corresponding BRS data, this approach would identify spatial correlations (using a GIS) between RCRA TSD facilities and reports of disamenities. Changes in these patterns over time (e.g., a reduction in reports of disamenties within a given distance from RCRA facilities) could be extrapolated to show trends in the vicinity of RCRA facilities.

Option 2. Qualitatively Discuss Changes in "Noxious Facilities." Using Industry Assessment data and specific engineering knowledge, this method would identify

[31] One direct approach to valuing aesthetic quality or historic importance is a contingent valuation (CV) survey. CV studies identify the willingness of people to pay for a particular resource or asset by asking them their preferences in multiple different scenarios and options. However, CV studies are resource intensive and their results are often difficult to interpret, because they rely on hypothetical responses and not on exhibited behavior. We therefore limit our methods to simpler approaches to the evaluation of these attributes.

pre-RCRA practices and waste facilities in key industries that would likely have been "noxious." Using Arthur D. Little, Inc. (1991) and BRS data, the method would estimate changes in the number of facilities and use of waste management practices since RCRA, and would then identify qualitatively the extent and type of effects of these changes on aesthetics.

3.3.5.2 Potential Impact of RCRA on Historical Sites

Option 3. Identify Proximity of RCRA sites to Historical Sites. This methodology would identify potential impacts of RCRA practices on historical areas. Using BRS data and a GIS, the approach would map large RCRA facilities (TSDs and large quantity generators) from several different years of BRS data. For all or a random sample of the sites, we would then develop a GIS layer of historical areas and overlay this layer on the RCRA sites (note that this analysis can also be expanded to include natural and cultural resources such as national parks).[32] Finally, we would identify changes over time in the number of RCRA sites close to historical districts.

3.3.5.3 Impact of RCRA on both Aesthetics and Historical Sites

Option 4. Perform Detailed Case Study of a Sample of Facilities. This method would use the Approach B sample or a separately collected sample and perform case studies. The case studies would identify patterns of land use, population density, and facility practice both before and after RCRA, and would estimate the potential impact of changes in waste management practices.[33]

While none of these approaches defines a value for the effects of RCRA on aesthetics and historic sites, all four address the range and magnitude of the possible effects. By performing case studies to address both historic and aesthetic effects or by using a combination of two of the other methods, it is possible to determine whether impacts on aesthetics and historical areas were likely to be considerable. If the scope of these benefits appears to be extensive, then additional resources can be allocated to analyzing a sample of facilities using either GIS technology or site-specific research.

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[32] The ability to map all historical areas will be limited by data availability. While some historical districts are mapped by the US Geological Survey and are available in national coverages for use in a GIS, other sites are determined by locality and may not be available from national sources. In addition, the data management requirements of a national GIS can be considerable.

[33] This method may be most appropriate in the context of Approach C (see discussion below), which requires collection of detailed site specific data as part of its modeling effort.

Exhibit B-4 in Appendix B contains a summary description of the methods for addressing improved aesthetics and historic preservation, including a brief description of data requirements for each.

3.3.6 *Approach B Summary*

Approach B provides a method for the detailed assessment of individual benefits attributes related to both improvements in TSD operations at active RCRA facilities, and to avoided hazardous waste sites due to closure of pre-RCRA TSDs. The approach outlines a method for identifying an appropriate facility sample and for modeling two scenarios: a baseline with-RCRA Subtitle C scenario that reflects damage from previous waste disposal and a without-RCRA Subtitle C scenario that estimates environmental damage from projected waste disposal in the absence of RCRA.

Based on these modeling results and other available information, Approach B presents methods for addressing four key exposure-related attributes.[34]

- Human health benefits
- Ecological benefits
- Avoided costs of alternate water supplies and site remediation
- Improved aesthetics and historic preservation

These attributes must be addressed separately, and benefits estimates will be additive or suitable for national extrapolation only to the extent allowed by the size and representativeness of the facility sample. However, to avoid the expense associated with sample selection and data collection Approach B proposes the use of the existing facility and modeling data for the sample of facilities studied in the *Corrective Action RIA*. In addition, the approach would examine the relative importance of each attribute, allowing the use of state-of-the art literature and methodologies for evaluation.

Our proposed Approach B is significantly more resource intensive than Approach A, and though it effectively analyzes the entire range of activities associated with TSDs, it still does not address the benefits of changes in waste management practices at RCRA-regulated facilities such as generators and transporters. In addition, though approaches to certain attributes address newly regulated RCRA facilities, the central focus of Approach B is on the wastes and facilities initially

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[34] Some data collected for Approach B may also be useful in examining Environmental Justice impacts related to RCRA; we discuss these impacts in Chapter 6.

regulated under RCRA. A thorough analysis of newly regulated wastes and industries would require an additional effort.

Approach B is also limited in its analytic options by the sample selection and data collection performed for the *Corrective Action RIA.* If it is determined that additional information or sample facilities are necessary to supplement the scope of an analysis, then a separate data collection effort would be required (note that an organized data collection effort from more than nine facilities would likely require an ICR). Even if the *Corrective Action RIA* is representative of the pre-RCRA universe, updating and adapting the RIAs model and analyses will demand considerable resources.

Finally, Approach B would address several important attributes and could provide a estimate for a substantial portion of the benefits of RCRA regulations affecting TSD facilities. However, as in Approach A, a complete examination of the benefits and costs of RCRA under this approach would require analysis of long-term benefits (Chapter 4), costs (Chapter 5), distributional impacts (Chapter 6) and program context attributes (Chapter 7).

3.4 APPROACH C: SITE SPECIFIC MODELING USING ORIGINAL DATA COLLECTION AND MODELING

Our proposed Approach C is similar to the site-specific modeling approach described in Approach B, but it would use different source data. While Approach B is based on the sample selection and available data of the *Corrective Action RIA,* Approach C outlines a methodology based on an original sampling and modeling effort. This approach allows more flexibility in study design to respond to issues such as resource limitations or analysis of a specific aspect of the RCRA Subtitle C program.

Our proposed Approach C would follow the same analytic outline as Approach B and involves several stages, including identification of sample facilities and collection of data; modeling analysis of facility data and identification of avoided damage; and estimation/characterization of attributes related to avoided damage. At each of these steps we present methodological alternatives that vary in required resources and in the comprehensiveness and precision of results. However, it is important to note that in an actual analysis, initial decisions about sample size and data collection may limit or expand later options for evaluation of some attributes.

3.4.1 *STEP 1. Identification and Selection of Facility Sample*

In Approach C, there is no pre-selected sample data. The most appropriate sample size and type is determined by specific analytic objectives. For instance, a limited number of detailed case studies may be most appropriate if the analytic objective is to characterize the range of possible benefits and costs of the RCRA or to develop a "worst case" damage scenario. Alternatively, if the objective is to reach a defensible national estimate of RCRA benefits and costs, then a larger, representative sample of facilities is necessary, providing a range of industries, geographic locations, and pre-RCRA waste management and disposal practices.

In selecting an appropriate sample under Approach C, it is important to identify the aspects of facilities that will allow the most accurate measurement of a variety of attributes. To address this, it is important to identify a range of:

- **Waste constituents.** These should reflect a variety of fate and transport behaviors and a range of effects on human health and ecological resources.

- **Facility sizes and management technologies.** Some pre-RCRA waste management units are likely to be riskier than others.

- **Proximate ecological resources**. This may include a range of land use, surface water resources, notable resources such as national parks and wilderness areas, and climates.

- **Human receptors.** This should include a range of population densities in various geographic areas of the country, to identify the likely range of health effects from different types of facilities.

- **Geology.** Because groundwater is an important pathway for human exposure, it is important to look at the effect of geology on the extent of damage from a facility.

Without knowing specific objectives in advance, we have identified a variety of data sets that may be useful in the development of sample frames and facility universe estimates. These include *Corrective Action RIA* data, as well as data from CERCLIS, RCRIS, BRS (for more recent facility information) and various state sources.[35] For a more detailed discussion of these sources see our description of Approach B above.

3.4.2 *STEP 2. Model Baseline and Without-RCRA Releases*

Approach C can be used in developing an estimate of the incremental benefits of improved waste management practices at active RCRA facilities, as well as benefits associated with avoided

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[35] Several states maintain publicly available facility and site information; however, if data are not readily available and the approach requires data from more than nine states, then an ICR may be necessary.

hazardous waste sites and TSDs. Furthermore, depending on sample selection, this approach could incorporate more recently regulated TSDs and wastes.

As in Approach B, it is necessary to identify pre-RCRA facilities that ceased or changed management of waste with the implementation of RCRA regulations. Using any of a number of sources, including *Corrective Action RIA,* RCRIS, state information sources, and CERCLIS, sample selection can be tailored to address specific analytic objectives.

In addition, Approach C would require the selection of a multi-media model that can be used to simulate a range of future release and damage scenarios. There are several multi-media models that are capable of providing reasonable scenarios for a variety of sites. To the extent that a model can be "customized" with site specific data in the place of default parameters, these models can provide reliable estimates of transport and exposure at individual facilities; however, if the preferred methodology is a set of case studies, then a site specific analysis based on actual field data may be preferable. We mention two of the available models with multi-pathway capability:[36]

- The MMSOILS model was used in the *Corrective Action RIA* in the analysis of human health risks. MMSOILS is a multi-pathway model that can calculate releases and exposure to contaminants through air, groundwater, overland flow and surface water, as well as ingestion of contaminants in soil.

- The MEPAS model is similar in function to MMSOILS; it is also capable of calculating the movement of releases through soil, groundwater, air, surface water, and overland runoff. Also like MMSOILS, it is capable of estimating human health risks from exposure through the various pathways.[37]

When the appropriate sample and model have been selected, Approach C analysis follows the same general steps as Approach B in developing an estimate of damages avoided under RCRA. A more detailed discussion of these steps is outlined above in our discussion of Approach B.

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[36] The HWIR 3MRA model is also under development and may be available for use in an analysis of RCRA human health and ecological benefits. Approach D (below) describes a methodology that uses this model.

[37] While a number of sources of information are readily available (e.g., RCRIS, CERCLIS data) Approach C data collection from facilities or states could require an ICR if the number of sample facilities (or states) exceeds nine.

3.4.2.1 Identify Level of Contamination in the Presence and Absence of RCRA

Our proposed Approach C requires site specific modeling of sample facilities to establish a level of contamination that has or would occur as a result of releases that took place before RCRA took effect. This effort may include collection of facility data from public records and databases, direct measurement of site conditions, and/or modeling of facilities based on engineering estimates and theoretical release scenarios. As in the *Corrective Action RIA,* it is necessary to identify a sample of facilities with pre-RCRA waste management units, though this sample can include facilities whose units were not regulated by RCRA until more recently. As in Approach B, this approach assumes that the risk of damage from new Subtitle C units at the sample facilities is negligible, due to monitoring and Subpart F Corrective Action requirements under RCRA prevention.

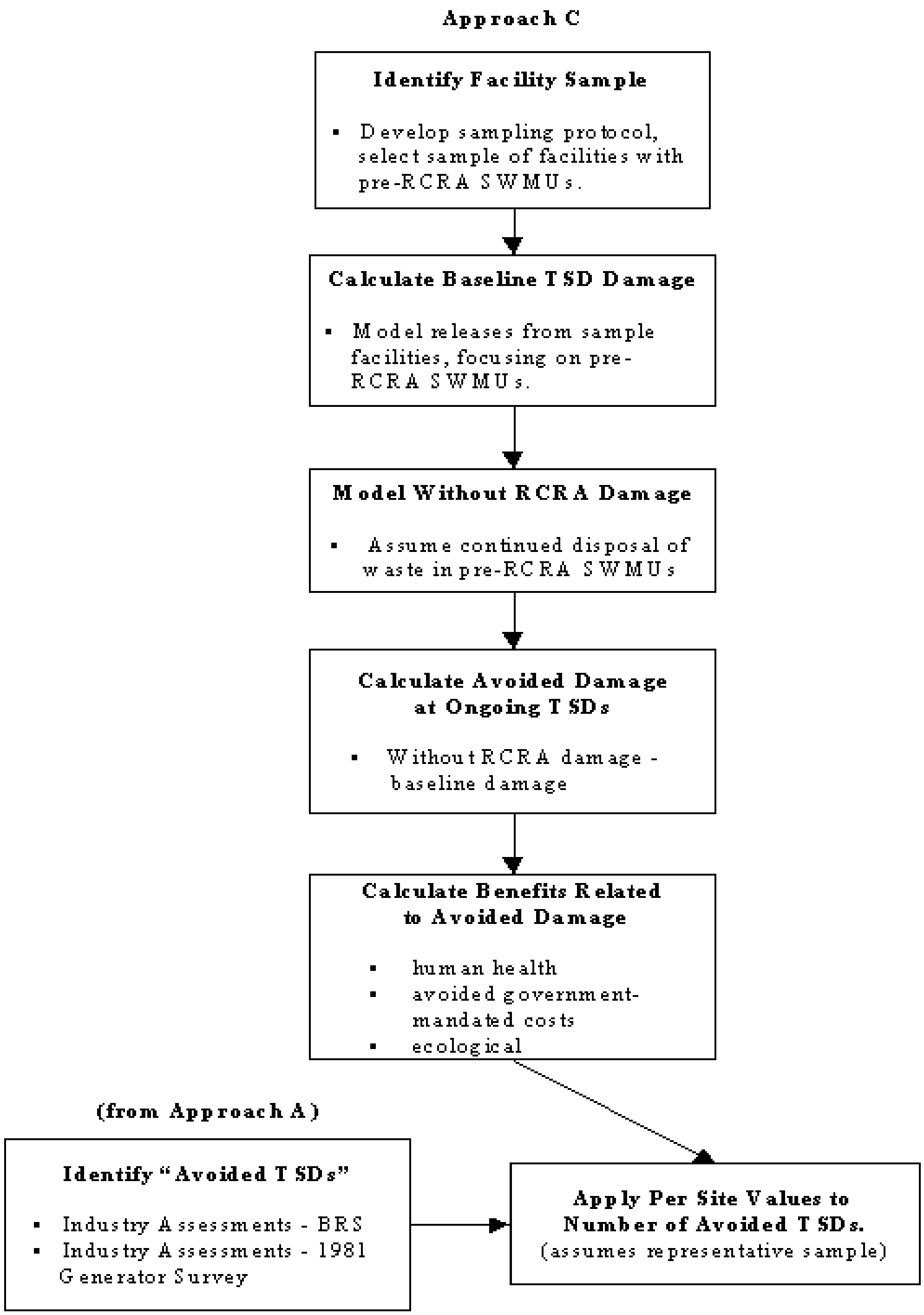
Approach C also requires modeling of the without-RCRA scenario assuming the continuation of waste disposal practices that were in place prior to RCRA. This requires facility information about past practices and wastes. As in Approach B, the extent of avoided damage attributable to the Subtitle C prevention program is the difference between this "continued disposal" damage and the actual with-RCRA estimate of contamination from the sample facilities.

3.4.2.2 Apply Modeling Results to "Avoided TSDs"

If Approach C involves a representative sample of facilities with pre-RCRA TSDs, then the avoided damage from closures can be measured by applying the range of damages identified at existing facilities to the number of avoided facilities identified in Approach A. As in Approach A, however, it is necessary to develop a range of estimates to reflect possible differences between the profile of existing contamination between sample facilities and the profile of existing contamination at facilities that closed under RCRA. In addition, this extrapolation is not possible if Approach C is implemented as a case study approach. Exhibit 3-4 provides a flow chart summary of Approach C.

Exhibit 3-4

SUMMARY OF APPROACH C TO ESTIMATING RCRA BENEFITS



3.4.3 *STEP 3: Estimate/Characterize Benefit/Cost Attributes*

Approach C modeling would provide an estimate of the number and extent of releases and environmental damage that have been avoided by the implementation of RCRA prevention programs at TSD facilities. The final stage of the approach addresses the four localized benefits that are addressed by Approach B: human health and ecological benefits, avoided costs, and aesthetics. The potential methods for estimating these attributes in Approach C are essentially the same as the methods identified in Approach B. For this reason we do not present detailed descriptions of the methodologies here. However, the development of an original modeling effort for each of these attributes requires attention to particular parameters. We list a few additional considerations below:

- **Human Health Effects:** It is important to determine the specific human health affects to be addressed by the model, as well as an average exposure time length, and to identify any high-end risk populations and scenarios (such as small children ingesting contaminated soil). Model selection will affect the extent to which specific human health risk parameters (e.g., individual, population, and MEI risks) can be estimated.

- **Ecological Effects:** It is important to determine the general ecology of the areas proximate to facilities and potential human uses (such as fishing), as well as the existing non-RCRA pollutants and damage in the area.

- **Avoided Costs:** It is important to consider the actual and future expected uses of groundwater, in addition to the availability of alternative supplies, and the possibility of economic incentives or regulatory requirements to install treatment or become part of a municipal system. It is also important to establish the model parameters to avoid double-counting avoided costs and human health benefits.

3.4.4 *Approach C Summary: Site Specific Approach Using Original Data Collection and Modeling*

Like Approach B, Approach C allows a site-specific analysis of a portion of the benefits related to both changes in practice at operating TSDs and to avoided hazardous waste sites due to closure of pre-RCRA TSDs. Also like Approach B, Approach C would use modeling to identify differences between with-RCRA and without-RCRA scenarios addressing the four key site specific attributes:[38]

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[38] Some data collected for Approach B may also be useful in examining Environmental Justice impacts related to RCRA; we discuss these impacts in Chapter 6.

- Human health benefits
- Ecological benefits
- Avoided costs of alternate water supplies and site remediation
- Improved aesthetics and historic preservation

In addition, Approach C provides considerable flexibility in determining the scope and focus of an analysis. For example, because it is based on original sampling and data collection, this approach may be used to target "newer" industries and wastes that were not originally regulated by RCRA, in addition to the universe of facilities whose SWMUs were regulated by 1982.

Approach C also provides a methodology for performing a detailed examination of a limited number of case studies to identify "worst case" facilities or to focus on specific industries or SWMU types. However, the benefits estimates will be additive or suitable for national extrapolation only to the extent allowed by the size and representativeness of the facility sample.

The chief limitation of the proposed Approach C is the resources that would be required to achieve a national estimate of benefits. In addition, the approach does not address RCRA generators and transporters, though site-specific modeling approaches could be used to address release scenarios at these facilities as well as TSDs.

Finally, as in Approach B, Approach C would address several important attributes and could provide an estimate for a substantial portion of the benefits of RCRA regulations affecting TSD facilities. However, a complete examination of the benefits and costs of RCRA under this approach would require analysis of long-term benefits (Chapter 4), costs (Chapter 5), distributional impacts (Chapter 6) and program context attributes (Chapter 7).

3.5 APPROACH D: PATHWAY MODELING APPROACH USING THE HWIR 3MRA MODEL

This methodology is similar to the other pathway modeling approaches in that it addresses benefits from reducing chronic risks to human health and to ecological resources. The approach hinges on the initial development of a without-RCRA scenario, describing how wastes would be generated and managed today if the waste management standards of RCRA were not applied. Using risk assessment damage functions, the approach compares the impacts of management in the without-RCRA scenario with the impacts of waste management in the with-RCRA scenario, where wastes are managed in compliance with the requirements of Subtitle C.

The approach is similar to the site-specific modeling approaches described in Approaches B and C, but uses different sources for data on the properties of the wastes and the locations and characteristics of projected waste management sites. The steps in this approach include:

- Identification of industries for modeling;

- Creation of a pre-RCRA scenario of waste generation and management (approximately 1978);

- Creation of a without-RCRA scenario of waste generation and management in a current year (approximately 2000);

- Modeling of waste disposal in sample facilities, and

- Modeling of environmental releases and resultant risks to human health and environmental resources.

Approach D and Approach B are similar in that they both employ a specific model to provide estimates of damage associated with waste management at a sample of "pre-RCRA" facilities. The following are principle differences between Approach D and Approach B:[39]

- **Source of waste data:** Approach B uses waste data based on individual sites (i.e., the specific facilities in the *Corrective Action RIA*), while waste data for Approach D are based on industry sectors;

- **Waste management facilities:** Approach B uses the sample of facilities at the *Corrective Action RIA* sites, while Approach D uses the sample of Subtitle D (i.e., non-hazardous) waste management facilities that are incorporated into the HWIR model; and

- **Methods for assessing risks:** Approach B uses Corrective Action data and the MMSOILS model, while Approach D uses the HWIR 3MRA (multimedia, multi-exposure pathway, multi-receptor risk assessment) model.

Approach D involves three basic steps in its development of modeling results.

[39] Approach C also presents a similar methodology based on pathway modeling at a sample of facilities, but does not specify a sample selection or modeling protocol that can be meaningfully compared to those described in Approaches B and D.

3.5.1 *STEP 1. Identification of Industries for Modeling*

Approach D portrays waste generation and management in various industries, beginning in the period before RCRA. The first step in this approach, therefore, is identifying which specific industries to model. This approach will only be feasible if data for a sufficient number of industries is available to create an overall picture of waste generation and management for the entire U.S. This effort is not expected to create a comprehensive picture of *all* industries, yet it is expected to produce a portrait that will represent benefits of good waste management for a significant proportion of wastes generated.

Candidates for modeling include the industries identified in the Office of Solid Waste *Industry Assessments* in the late 1970's. These reports profiled generation and management of hazardous waste in a number of industrial sectors. Other industries which were not included in those profiles may also be good candidates, if data are available.

3.5.2 *STEP 2. Creating Scenarios of Waste Generation and Management*

An initial set of industries will be assembled as candidates to model waste generation and management in both a "true" pre-RCRA scenario and a counterfactual, without-RCRA scenario. These are defined and explained below.

3.5.2.1 Pre-RCRA Scenario

For each industry selected, the next step would be to create a scenario describing waste generation and management in a pre-RCRA year (prior to promulgation of RCRA regulations). For each industry, the pre-RCRA scenario will note what wastes are generated, in what volumes, in what forms, what constituents are in the waste, and how they are managed. Existing data sources should be sufficient to provide information about waste generation and management. Much of the data in the *Industry Assessments* was collected to learn how waste was managed; the resulting reports provided information about the threats posed by mismanaged hazardous waste.

This information would need to be updated by including data on wastes which were *generated* in the pre-RCRA year, but were not yet *tracked* (or identified as hazardous) by the RCRA program. By bringing together data from a variety of sources, it should be possible to create a reliable and reasonably accurate scenario describing hazardous waste management before RCRA management practices were employed.

3.5.2.2 Without-RCRA Scenario

Working from the pre-RCRA scenario (waste management before RCRA standards), the next step would be to create the without-RCRA scenario. This would require extrapolating waste generation data for each industry from the pre-RCRA scenario (approximately 1978) up to today. This extrapolation would require careful estimation, examining actual generation in each year as well as industry trends, other regulatory initiatives, and economic factors that influenced industrial production and waste generation in each year.

The end product of this task would be a scenario describing generation and management of hazardous waste *as it would be today,* if RCRA management standards were not in place. Specifically, the scenario would include information on:

- Waste streams generated
- Quantities generated/managed
- Types of management units used (landfills, surface impoundments, waste piles, open dumping, etc.), and
- Waste constituents and concentrations.

3.5.2.3 Location of Management Units

To describe the effects of continued waste management under pre-RCRA practices, we would need to determine how wastes would be managed in the absence of RCRA standards. The pre-RCRA scenario would include information on the types of management units used. In order to understand the impacts of substandard waste management practices, waste disposal at particular locations would be modeled. The approach assumes that wastes would be disposed at typical non-hazardous waste management facilities (this approach understates the risks from non-RCRA waste management, since wastes could simply be dumped).

The 1985 *Screening Survey of Industrial Subtitle D Establishments* described data on locations of facilities and waste management units, representing over 150,000 establishments managing non-hazardous wastes. A representative sample of these facilities was assembled by the OSWER office of Solid Waste (OSW) to create the Site Survey Database for the 3MRA model.

This approach would use this sample database to represent disposal of wastes at typical non-hazardous waste units around the country. Quantities of waste generated each year can be modeled as being disposed at these typical facilities, in the types of units that were used historically to manage these wastes, as indicated by the industry data.

There are several advantages to use of this database. These include:

- **Representative data on locations and types of facilities**: The sites are representative of the types, sizes, and geographic locations of non-hazardous waste management units at which waste might be disposed for the universe of these units known in 1986. Assuming some advances in regulation since the initial RCRA regulations were promulgated in 1980, these sites most likely represent waste disposal alternatives that are at least as protective as those which might be used in the absence of RCRA; in fact, they are likely to be more protective.

- **Characterization of the sites, include attributes affecting fate and transport of contaminants:** OSW has conducted extensive site-specific characterization of the sample sites, including human receptors, water bodies and watersheds, soils, and other ecological receptors. EPA has supplemented this site-specific data with regional data on meteorological conditions and water quality and aquifer data.

- **Representative data to characterize management units:** This database also includes data on the various types of management units used for non-hazardous waste management, and characteristics (size, location, etc.) of these units. The sampling method and the Monte Carlo methods in the 3MRA model would provide statistically valid representations of waste management at the universe of non-hazardous waste management sites around the country.

3.5.3 *STEP 3. Modeling Environmental Impacts*

This approach would use the 3MRA model which has been developed to provide risk assessment supporting the Hazardous Waste Identification Rule. The 3MRA model is the result of years of effort from both OSWER and Office of Research and Development (ORD), and has been extensively reviewed and tested.

The model is designed to estimate human health and ecological risks from management of wastes in waste management units that are not compliant with RCRA Subtitle C standards. Inputs to the modeling would include:

- Waste quantities and characteristics from the without-RCRA scenario;

- Data on waste management units from the Site Survey database;

- Site-specific data on watersheds, water bodies, soil characteristics, and human and ecological receptors;

- Region-specific data on meteorological properties, groundwater and surface water, and other ecological receptors; and

- Supplementary national-level data.

The result of the modeling effort would produce estimates of human health (both individual and population) risks and ecological risks that would be present *today* if RCRA standards were not followed. These risks would be compared to those present in the baseline condition (waste management in these industries today, as regulated by RCRA management standards). The difference in chronic human health and ecological risks would address two of the major benefits attributes associated with RCRA Subtitle C standards. Exhibit 3-5 provides a flow chart summary of Approach D.

As with Approaches B and C, Approach D modeling data might also be used to support estimates of avoided costs; additional methodologies presented as part of Approach B would also be relevant to this approach.[40] Finally, as with the other benefits approaches, a complete examination of the benefits and costs of RCRA under Approach D would require analysis of long-term benefits (Chapter 4), costs (Chapter 5), distributional impacts (Chapter 6) and program context attributes (Chapter 7).

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[40] Note that engineering cost estimates of alternative water supplies are not likely available as part of the 3MRA model; however, it may be possible to use cost data from *The Corrective Action RIA* or other sources to provide general estimates of avoided costs.

Exhibit 3-5

SUMMARY OF APPROACH D TO ESTIMATING RCRA BENEFITS

Approach D

Identify Pre-RCRA Industries and Practices

- Identify target industries using pre-RCRA data on waste generation and disposal.

Develop Without-RCRA Scenario

- Develop scenario of continued waste disposal absent RCRA in target industries.

Model Without-RCRA Damage

- Use HWIR 3MRA Model to identify impacts of without-RCRA waste disposal.

Calculate Benefits Related to Avoided Damage

- human health
- avoided government-mandated costs
- ecological